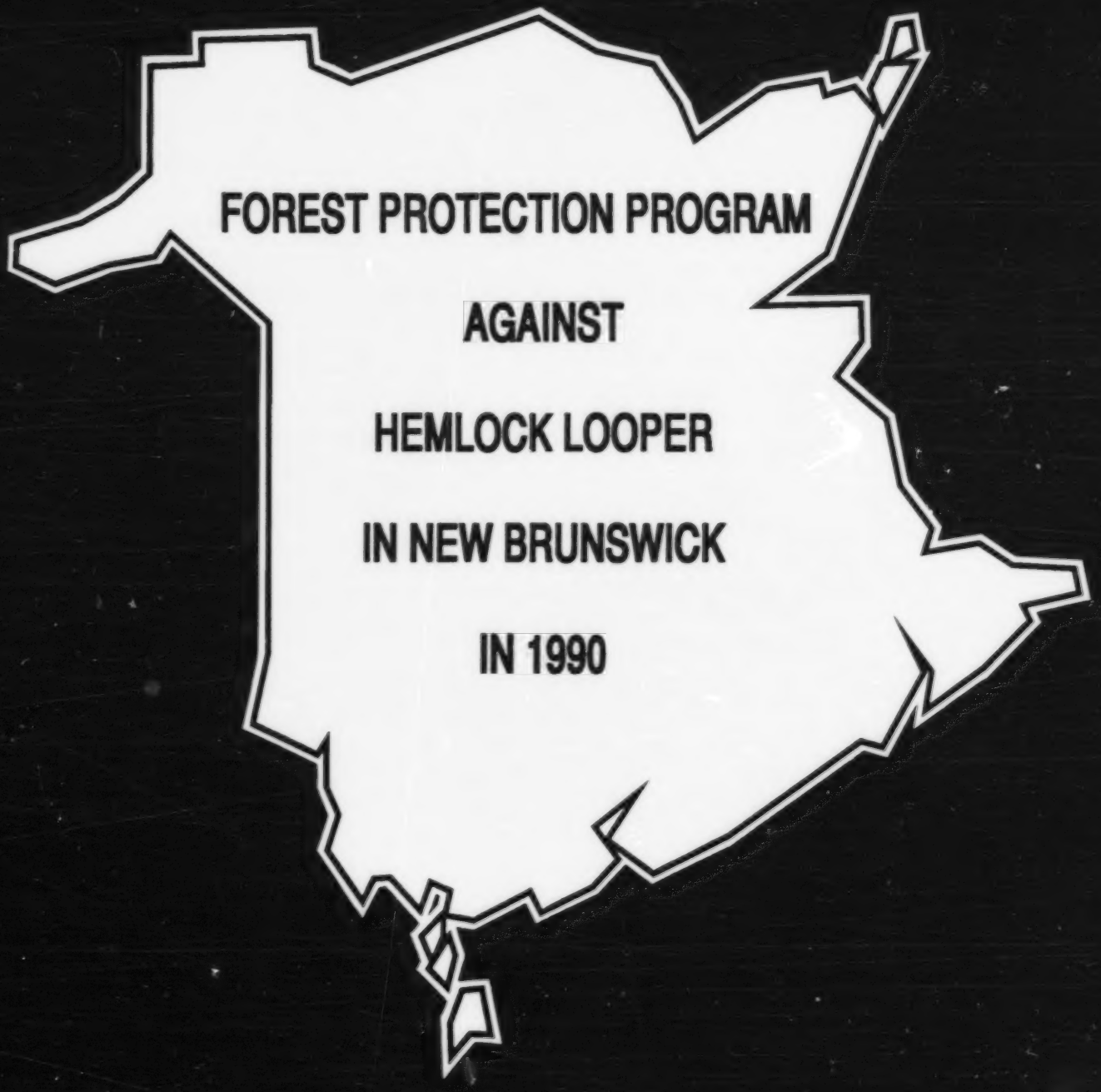
New Nouveau
Brunswick



FOREST PROTECTION PROGRAM AGAINST HEMLOCK LOOPER IN NEW BRUNSWICK IN 1990

Natural Resources & Energy | Ressources naturelles et énergie

91-05677/

Doc.: LOOPER.RPT

FOREST PROTECTION PROGRAM AGAINST HEMLOCK LOOPER IN NEW BRUNSWICK IN 1990

Lester Hartling and Nelson Carter

Timber Management Branch
Forest Pest Management Section
Department of Natural Resources & Energy
Fredericton, New Brunswick
1991

Hon. Morris V. Green
Minister

Bryan Walker
Deputy Minister

(aussi disponible en français)

SUMMARY

A hemlock looper outbreak causing severe damage to balsam fir was detected in 1989 in north-central New Brunswick. This was the first outbreak recorded in New Brunswick. Based on an egg survey at 128 locations in the fall of 1989, an area of 20 000 ha was delineated as containing populations suspected to be great enough to cause significant feeding damage in 1990.

Three spray blocks totalling 21 160 ha were delineated and treated for foliage protection and possible population suppression. Two blocks (H&L), totalling 17 805 ha, received three applications of insecticide several days apart in the following sequence: fenitrothion (Sumithion), Bacillus thuringiensis (B.t.) (Futura XLV), and fenitrothion. Each application of fenitrothion was sprayed at 210 g/1.46 L/ha and the B.t. was applied at 30 BIU/2.03 L/ha. The third block (P) 3 355 ha in size was treated with two applications of B.t. at 30 BIU/2.03 L/ha. All applications were made with T.B.M. aircraft, using boom and nozzle spray systems. Spraying commenced June 25th and was completed July 6th.

Two spray blocks (H&P) were monitored for efficacy but due to limited accessibility, assessment of the third block (L), located between the other two, was limited to assessment from the air during an aerial survey of defoliation. Plot averages of pre-spray egg densities ranged from 5 to 90 eggs per 100-cm branch. Plot averages of pre-spray larval densities ranged from 6 to 50 larvae per branch. Pre-spray populations were generally greater in Block H than in Block P.

The spray program was assessed in three ways, namely: foliage protection, larval survival and population change (i.e. egg density). Upon hatching, hemlock looper larvae feed on current year's foliage and switch to old years' foliage in later instars. This behaviour makes it difficult to assess damage to the older age classes of foliage caused by feeding in one growing season. To assess foliage protection due to spraying, trees were selected prior to shoot flushing and assessed for levels of defoliation on all age classes of foliage. After shoot flush, following spraying and upon completion of looper feeding, the same trees were reassessed for defoliation. The general condition of the monitored trees in Block P (2 x B.t.) improved in all 5 plots with an increase in total foliage ranging from 25 to 59% per plot average. In Block H (Fen. + B.t. + Fen.) tree condition improved 22% at one plot while two other plots maintained their healthy condition of little foliage loss. However, two remaining plots experienced a decrease in total foliage of 24% and 35%.

Program assessment was confounded because there were no areas having high looper populations which were left unsprayed. This was because of the decision to include virtually all the forecast within the spray blocks. Although the trees at two plots in Block H deteriorated in terms of foliage retained on the trees, it is not known how much worse damage could have been without spraying. Therefore the change in total foliage on trees from 1989 to 1990 is only a measure of the improvement or decline of the assessed trees and can not be used to determine if one treatment was more effective than another, or how beneficial was spraying compared to no treatment.

If only damage to current year's foliage (1990) is considered, mean defoliation at the plot level, attributed to hemlock looper was 5 to 41% for Block H (Fen. + B.t. + Fen.) and 4 to 28% for Block P (2 x B.t.).

Although there were no untreated check areas at similar population levels to that found in spray blocks, several plots in southwestern New Brunswick, with egg counts judged to be too low to warrant insecticide treatment were monitored periodically throughout the summer. Larval survival, from hatch through to predominately third and fourth instar development was much lower in the treated plots compared to untreated plots. Similarly, egg counts in sprayed plots decreased dramatically from the fall of 1989 to 1990, while showing no change or increasing in the untreated plots. How much these differences can be attributed to insecticide-induced mortality or natural population dynamics is unknown.

Based on results of an aerial survey of defoliation, the area of defoliation attributed to hemlock looper in 1990 was 3 477 ha, of which 78% included spruce budworm defoliation still visible from the air. Damage was limited to an area in northern New Brunswick. It was estimated that 1 822 ha (9%) of the 21 160 ha sprayed was defoliated by looper, or looper in association with spruce budworm. On a treatment basis, 9% of the area treated with Fen. + B.t. + Fen. and 8% of the block treated with 2 x B.t. had detectable defoliation.

Based on defoliation in 1990 and results of the fall egg survey, areas identified where pockets of defoliation are expected to occur in 1991 are 22 692 ha in northern New Brunswick and 6 771 ha in Charlotte County in southwestern New Brunswick. Populations appear to have risen at many plots in the latter area since last year.

ACKNOWLEDGEMENTS

The on-site surveys conducted to time and assess the efficacy of this very first spray program against hemlock looper in New Brunswick were ably coordinated by Peter MacNutt, assisted by permanent and casual staff of the Forest Pest Management Section.

The aerial defoliation surveys were conducted jointly by Wilf Patterson (DNR); and Forestry Canada officials, Bruce Pendrel (1989) and Ed Hurley (1990).

Specifically, the information contained in this report reflects the efforts of full-time staff of the Forest Pest Management Section: Carroll Cameron, Ross Farquhar, Dan Lavigne, Robert MacGregor, Peter MacNutt, Danny O'Shea, Wilf Patterson, Janet Proude and Greg Simpson. Their efforts, and those of numerous summer staff, are gratefully acknowledged.

A draft of this report was reviewed by the following people: Hubert Crummey (Newfoundland Department of Forestry and Agriculture), Dave Davies (Forest Protection Ltd.), Dan Quiring (University of New Brunswick), Henry Trail (Maine Forest Service), Rick West (Forestry Canada - Newfoundland and Labrador Region) and Dan Lavigne, Peter MacNutt and Wilf Patterson (New Brunswick Department of Natural Resources and Energy). Their comments and constructive criticism are greatly appreciated, however, comments and conclusions in this report do not necessarily reflect all their viewpoints.

Janet Lynch is acknowledged for her patience in typing the numerous drafts of this manuscript.

TABLE OF CONTENTS

	Page
SUMMARY	i
ACKNOWLEDGEMENTS	iii
LIST OF TABLES	v
LIST OF FIGURES	vi
1. BACKGROUND	1
2. SPRAY PROGRAM	
2.1 Area Sprayed and Treatments	1
2.2 Criteria for Timing Spray Applications	5
3. ASSESSMENT OF SPRAY PROGRAM	
3.1 Pre-Spray Population - Egg and Larval Counts	6
3.2 Foliage Protection	7
3.3 Larval Survival in Spray Blocks and Certain Untreated Plots	8
3.4 Change in Egg Counts Following Spray Applications	11
4. AERIAL ASSESSMENT OF DEFOLIATION CAUSED BY HEMLOCK LOOPER	15
5. FORECAST FOR 1991	15
REFERENCES	19
APPENDICES	
A Scatter diagram of relationship between hemlock looper larval hatch and larval development versus accumulated degree days.	20
B Summary of hemlock looper larval development at time of block openings and at time blocks were sprayed.	22
C Hemlock looper egg extraction process as used in New Brunswick.	24

LIST OF TABLES

		Page
Table 1.	Biological criteria initially specified for timing spray applications for each spray block.	5
Table 2.	Hemlock looper egg and larval counts (plot averages) prior to insecticide treatment.	7
Table 3.	Change in estimated total foliage on trees before and after spraying.	10
Table 4.	Defoliation of current year's foliage.	10
Table 5.	Change in hemlock looper egg population from the fall and winter of 1989/90 to the fall of 1990.	14
Table B-1	Summary of hemlock looper larval development at time of block openings and at time of spraying.	23

LIST OF FIGURES

		Page
Figure 1.	Area of defoliation in New Brunswick attributed to hemlock looper in 1989.	2
Figure 2.	Hemlock looper forecast for 1990, based on 1989 egg survey.	3
Figure 3.	Areas sprayed for control of hemlock looper in northern New Brunswick in 1990.	4
Figure 4.	Change in mean amount of total foliage per fir tree per plot in blocks treated with insecticide against hemlock looper in New Brunswick in 1990.	9
Figure 5.	Survival of hemlock looper over time and by larval development index.	12
Figure 6.	Area of defoliation attributed to hemlock looper in New Brunswick in 1990.	16
Figure 7.	Hemlock looper forecast for 1991 in New Brunswick, based on egg surveys and aerial survey of defoliation in 1990.	18
Figure A-1	Scatter diagram of hemlock looper larval development versus accumulated degree days from April 1 to July 31, 1990 (threshold of 3°C).	21

FOREST PROTECTION PROGRAM AGAINST HEMLOCK LOOPER IN NEW BRUNSWICK IN 1990

1. BACKGROUND

A hemlock looper outbreak[1] causing severe damage to balsam fir was detected in the summer of 1989 in north-central New Brunswick, in the Christmas Mountains area (Figure 1) and was the first outbreak recorded for the Province (Magasi; 1990). Areas of defoliation, totalling 3 817 ha, were identified by aerial surveys jointly conducted by Provincial and Federal forestry staff.

The Department of Natural Resources and Energy (DNRE) conducted an egg survey in the fall of 1989 to determine whether populations were high enough to warrant a protection program in 1990. Local information for population/damage forecasting was non-existent hence methods used in Newfoundland[2] were adapted for use[3]. Ninety-three plots were sampled from a 206 000 ha area in northern New Brunswick, surrounding the observed outbreak. In addition, 35 plots were sampled in southern New Brunswick where looper activity had been detected throughout the summer. Based on results from the egg survey, an area of 20 000 ha was delineated as containing populations suspected to be great enough to cause significant feeding damage in 1990 (Figure 2). Subsequently, an area of 21 160 ha in northern New Brunswick encompassing virtually all the forecast area was identified for treatment in 1990. The objective was foliage protection and population suppression.

This report provides results of an operational assessment of the very first hemlock looper control program in New Brunswick. Forestry Canada-Maritimes also conducted research in one operational spray block (P) sprayed with B.t. only, but those results will be reported elsewhere.

2. SPRAY PROGRAM

2.1 Area Sprayed and Treatments

The area at risk from looper feeding was divided into three spray blocks (Figure 3). Aerial spray applications were made by Forest Protection Ltd. (FPL) (Davies, 1990). The two larger blocks (H & L), totalled 17 805 ha in area and received three applications of insecticide several days apart in the following sequence: fenitrothion (Sumithion), Bacillus thuringiensis (B.t. - Futura XLV), and fenitrothion. Fenitrothion was applied at 210 g/1.46 L/ha and the B.t. at 30 BIU/2.03 L/ha. The smallest block (P), 3 355 ha in size, was treated with two applications of B.t. at 30 BIU/2.03 L/ha per application, again with several days between applications. All applications were made with T.B.M. aircraft, using boom and TeeJet 110-10 nozzles (Bev McDougall, personal communications, March 1991).

---

1. Brought to DNR's attention by a Forestry Canada-Maritimes official.
2. Forestry Canada - Newfoundland and Labrador Region.
3. Information on egg survey methodology and damage forecast thresholds are described in Section 5 - FORECAST FOR 1991.

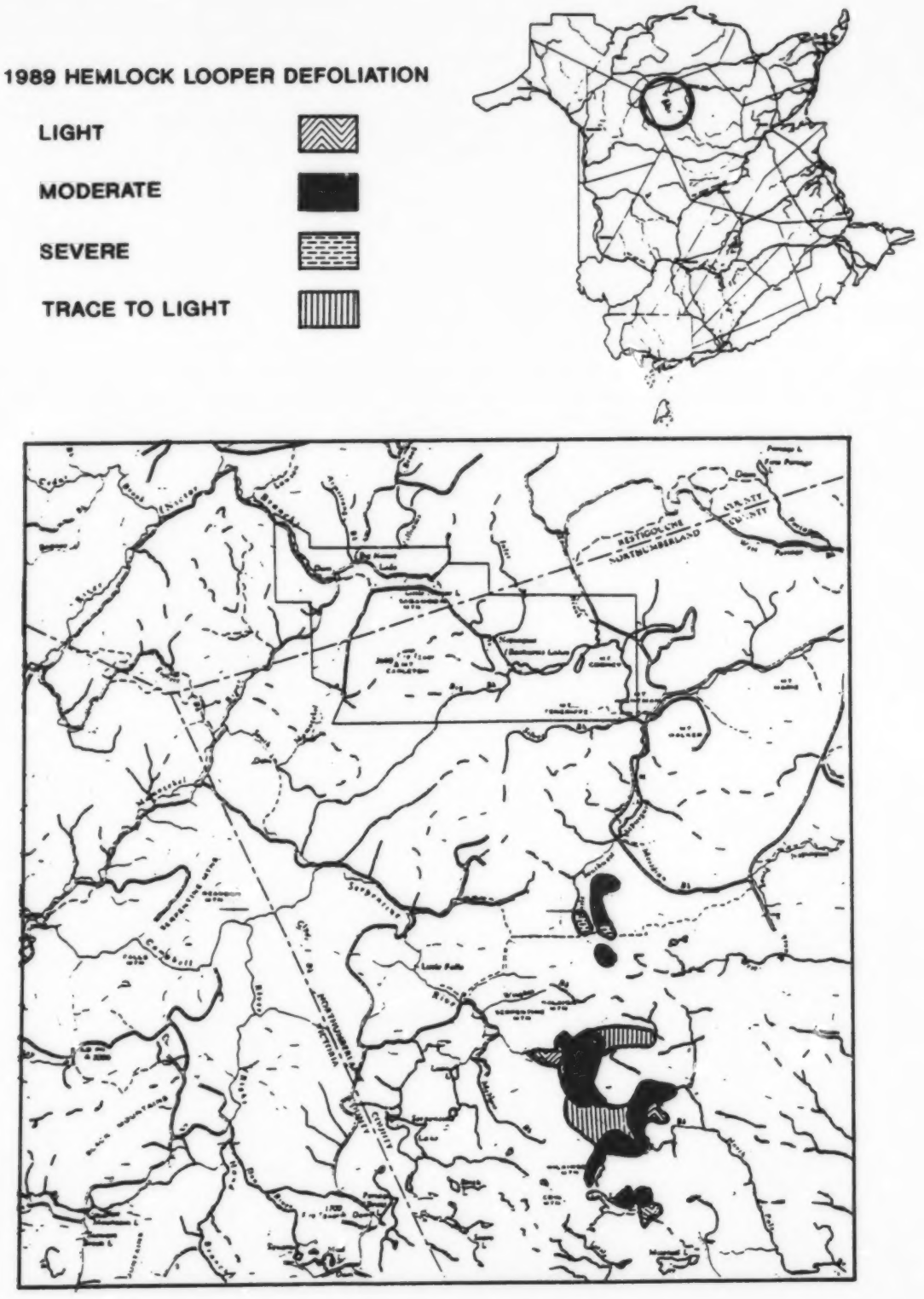


Figure 1. Area of defoliation in New Brunswick attributed to hemlock looper in 1989.

HEMLOCK LOOPER
FORECAST FOR 1990

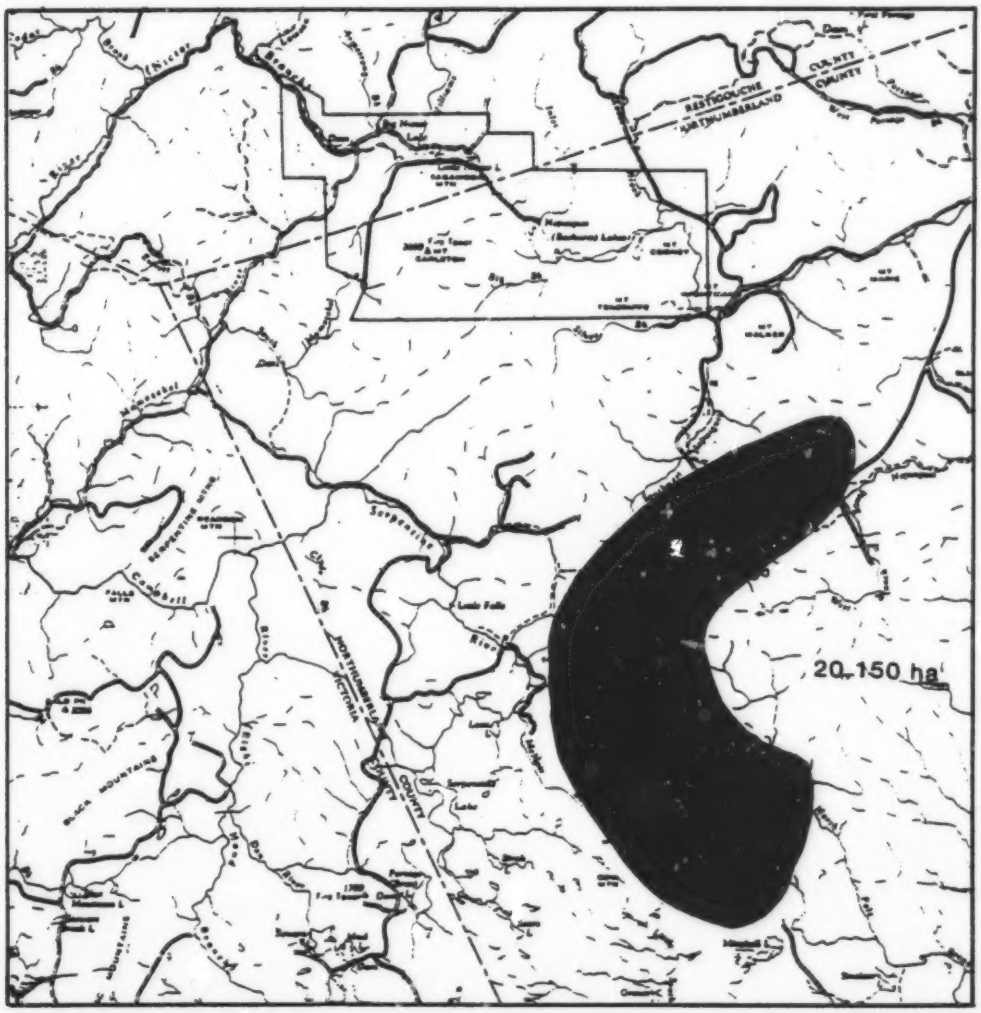


Figure 2. Hemlock looper forecast for 1990 in New Brunswick, based on 1989 egg survey.

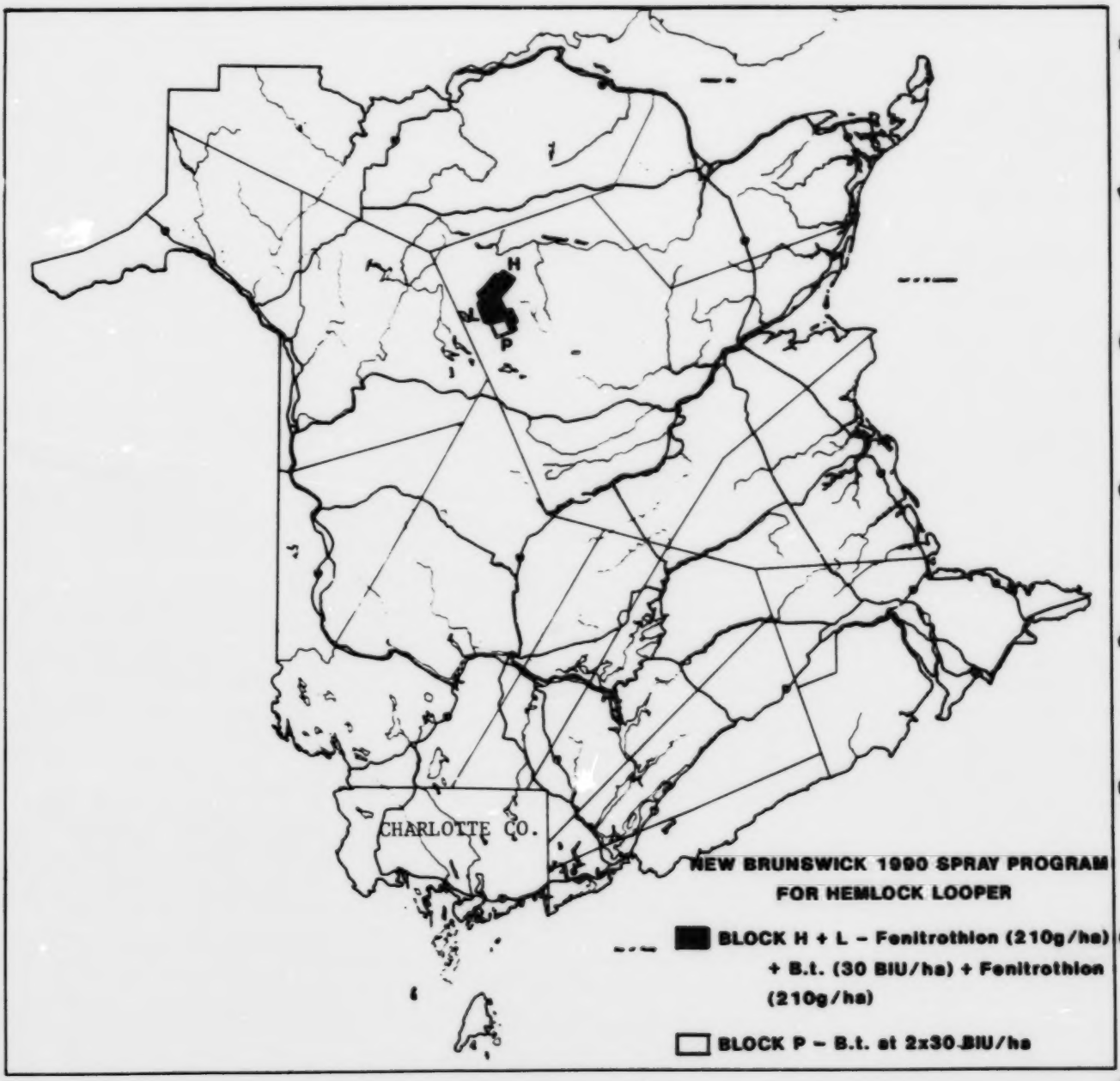


Figure 3. Areas sprayed for control of hemlock looper in northern New Brunswick in 1990.

2.2 Criteria for Timing Spray Applications

In 1990, DNRE staff monitored hemlock looper larval hatch and larval development in both the northern and southern parts of the spray area. Five plots, of ten trees per plot, were established in blocks H and P. Block L had limited accessibility but one plot of five trees was established in its southern end. Daily collections from a subset of plots were carried out to monitor insect development from first hatch until spraying was completed. Several hundred larvae were examined daily, using headcapsule measurements, color, and marking characteristics as criteria to determine larval development. Headcapsule widths for each instar were based on work done the previous winter when larvae had been reared from eggs removed from branches collected during the 1989 egg survey. Although sample sizes were limited, these data provided the only available New Brunswick reference material. Based on work in 1990, a larger data set will be available for 1991. The relationship between larval hatch and larval development vs. accumulated degree days was determined from the data collected in 1990 (Appendix A).

When the blocks were deemed to be biologically ready for treatment for each spray application, FPL was notified. The biological criteria initially specified for timing the first two spray applications (Table 1) were based on recommendations from provincial (Crummey, personal communications) and federal (West, personal communications) forestry officials who had first-hand experience with operational and research spray programs against hemlock looper. In Newfoundland, the recommendation was that the appearance of 10% 2nd instar larvae (L2) served as a good indicator that most insects had hatched and were therefore susceptible to insecticide.

Table 1. Biological criteria initially specified for timing spray applications for each spray block.[1]

Treatment	1st Application	2nd Application	3rd Application
Fenitrothion & B.t. & Fenitrothion (Blocks H & L)	90% L1 & 10% L2 (Larval Index = 1.1) with fir shoots flushed.	50% L1 & 50% L2 (Larval Index = 1.5) with fir shoots flushed.	Nominal 5-7 days based on field observations.
B.t. & B.t. (Block P)	90% L1 & 10% L2 (Larval Index = 1.1) with fir shoots flushed.	50% L1 & 50% L2 (Larval Index = 1.5) with fir shoots flushed.	N/A

1. Calculation of Larval Index is explained in Appendix B.

These criteria had to be modified to reflect conditions in the field. Due to poor weather for spraying, the first insecticide application was delayed 5-7 days from when blocks were deemed to be "biologically ready" (June 20th). This meant that the blocks received first application when the larval index ranged from 1.1-2.0 (Block H & L) to 1.9-2.0 (Block P); and received second application when the larval index ranged from 2.4-3.1 (Block H & L) to 3.1 (Block P). (Larval developments at the time blocks were opened for first, second, and third insecticide applications, and actual spray dates, are summarized in Appendix B). Spraying commenced on June 25th and was completed by July 6th.

3. ASSESSMENT OF SPRAY PROGRAM

The spray program was assessed in terms of foliage protection, larval survival, and change in egg density from 1989-90 to 1990-91. The primary weakness in the assessment is that there were no untreated check plots at similar population levels for comparison. This was because of the decision to include the entire forecast within the spray blocks both for foliage protection and possible population suppression.

The northern and southern portions of the spray area were monitored for efficacy. Five plots were established in both Block H (the most northern block) and Block P (the most southern block). In total, 100 trees were assessed for egg counts, 95 trees for pre-spray larval counts, and 160 trees for defoliation. Time constraints and limited accessibility did not permit a similar assessment in Block L, located between the other two blocks, although it was assessed from the air during an aerial survey of defoliation.

The two primary hosts for hemlock looper are balsam fir and hemlock. The major tree species in the spray blocks were fir and spruce, hence, assessments were restricted to balsam fir.

3.1 Pre-Spray Population - Egg and Larval Counts

Pre-spray densities were determined by sampling eggs prior to larval hatch and by sampling larvae after they hatched. Pre-spray egg densities were established for ten trees at each of 5 plots in Blocks H and P. A 100-cm lower-crown branch was cut from each tree. Eggs were removed and counted using the bleach extraction method (Appendix C).

Pre-spray larval densities were established at the same 5 plots in Block H and P. Beating samples were not possible due to the height of the trees. A mid-crown branch was removed from each of 10 trees per plot.[1] An attempt was made to cut 45-cm branches, drop to a tarpaulin, and count the larvae. Since larvae fell off the branch when it hit the

1. Only 5 trees were sampled at one plot in Block H.

tarpaulin, all larvae had to be counted irregardless of deviations in branch length. In reality, 81% of the branches ranged from 41-60 cm in length. Cut branches which hit any other branches in falling were discarded and another sample taken.

On average looper egg and larval populations were greater in Block H compared to Block P (Table 2). Plot averages ranged from 5-90 eggs per branch as compared to 10-29 eggs per branch, respectively. Pre-spray larval counts ranged from 6-50 per branch in Block H, compared to 14-25 per branch in Block P.

Table 2. Hemlock looper egg and larval counts (plot averages) prior to insecticide treatment.

Block I.D.	Plot No.	Pre-Spray Populations: Eggs /100 cm Branch (avg.)	Eggs Sample Size (trees/plot)	Larvae /Branch (avg.)	Larvae Sample Size (trees/plot)
H	1	5.3	10	5.8	10
	2	10.5	10	24.3	10
	3	30.4	10	29.6	10
	4	89.9	10	35.4	5
	5	85.5	10	49.9	10
	Avg.	44.3		29.0	
P	1	12.8	10	20.8	10
	2	11.9	10	20.0	10
	3	13.3	10	14.3	10
	4	29.0	10	25.1	10
	5	9.5	10	15.8	10
	Avg.	15.3		19.2	

3.2 Foliage Protection

Unlike spruce budworm, which feed primarily on current year's foliage, hemlock looper larvae feed on current year's foliage upon hatch and switch to old years' foliage in later instars. This behaviour makes it more difficult to assess damage to older foliage caused by this insect in one growing season. To assess foliage protection due to spraying, trees were selected prior to shoot flushing and assessed for levels of defoliation on all age classes of foliage. Based on ocular assessments of whole trees (using binoculars) and examination of a mid-crown branch, each tree was assigned a defoliation category within 10% classes. After shoot flushing, following spraying and upon completion of looper feeding, the same trees were reassessed for defoliation on all age classes of foliage using the same methodology. These same trees were assessed for defoliation of the current year's foliage based on an ocular assessment (using binoculars) and examining

a mid-crown branch cut from each tree. In total, 75 trees from 5 plots were assessed in Block H and 85 trees from 5 plots in Block P.

In Block H (Fen. + B.t. + Fen.) tree condition improved 22% at one plot while two other plots maintained their healthy condition with little foliage loss (Figure 4; Table 3). However, trees in two other plots experienced a decrease in total foliage of 24% and 35% (Figure 4; Table 3). In contrast, the general condition of the monitored trees in Block P (2 x B.t.) improved in all plots, with increases in total foliage ranging from 25-59% per plot average (Figure 4; Table 3).

The weakness in the assessment, as previously mentioned, is that there were no areas having high looper populations which were left unsprayed. Therefore, although the trees at two plots in Block H actually deteriorated in terms of foliage retained, we do not know how much worse they could have been without spraying. The change in total foliage on the trees from 1989 to 1990 therefore is only a measure of improvement or decline of assessed trees and can not be used to determine if one treatment was more efficacious than the other, or how beneficial spraying was compared to leaving them untreated.

If only damage of current year's (1990) foliage is considered (Table 4), mean defoliation at the plot level ranged from 5-41% for Block H (Fen. + B.t. + Fen.) and 21-70% for Block P (2 x B.t.). Note, however, that in the plots at Block P, there was a significant spruce budworm population ranging from 16-38 L3 per branch. Before spraying took place, defoliation attributed to budworm was very noticeable. If defoliation of current year's foliage is adjusted to account for the amount of budworm feeding, looper defoliation at Block P averaged 4-28%.

3.3 Larval Survival in Spray Blocks and Certain Untreated Plots

Changes in population density were monitored through the summer in Blocks H and P. Periodic sampling was done at 5 plots in each spray block. These were the same 10 plots monitored for larval development, pre-spray egg and larval densities, and defoliation. The number of trees sampled per block varied for each sampling period, ranging from 10-60 trees/block. A mid-crown branch was removed from each tree, dropped to a tarpaulin, and the larvae counted.

There were several plots in southwestern New Brunswick (Charlotte County) where egg counts were judged to be too low to warrant insecticide treatment. These areas (7 plots of 5 trees/plot), however, were still monitored periodically throughout the summer to assess larval survival. Trees were sampled in a similar manner to the plots in the spray blocks. Larval survival, in this case, was based on the change in population level from larval hatch until most individuals had become 3rd and 4th instars.

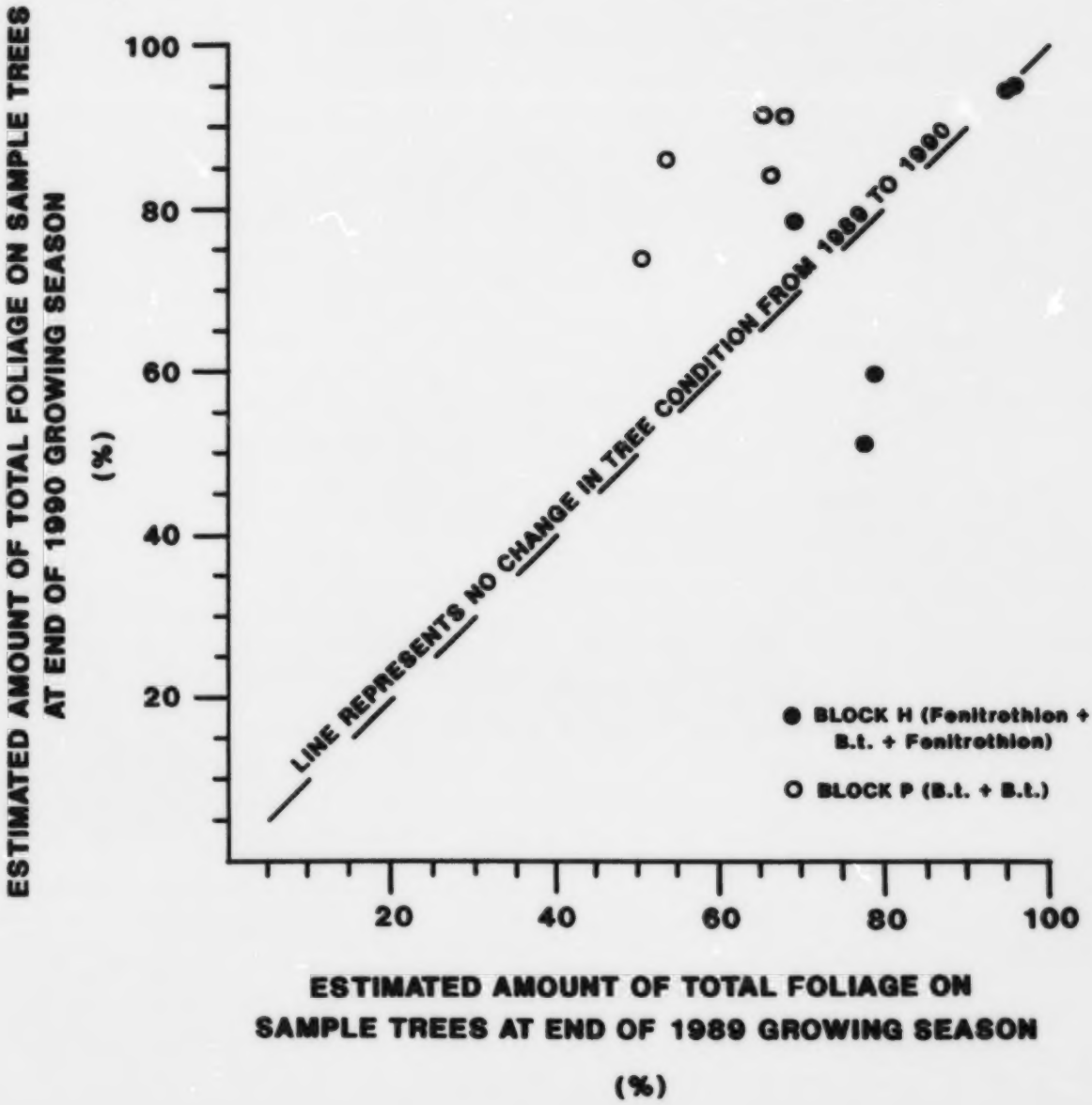

ESTIMATED AMOUNT OF TOTAL FOLIAGE ON SAMPLE TREES AT END OF 1990 GROWING SEASON (%)
100
80
60
40
20
LINE REPRESENTS NO CHANGE IN TREE CONDITION FROM 1989 TO 1990
BLOCK H (Fenitrothion + B.t. + Fenitrothion)
BLOCK P (B.t. + B.t.)
20
40
60
80
100
ESTIMATED AMOUNT OF TOTAL FOLIAGE ON SAMPLE TREES AT END OF 1989 GROWING SEASON (%)

Figure 4. Change in mean amount of total foliage per fir tree per plot in blocks treated with insecticide against hemlock looper in New Brunswick in 1990.

Table 3. Change in estimated total foliage on fir trees before and after spraying.

Spray Block	Plot No.	No. Trees Sampled	Total Foliage Present on Tree: Prior to Shoot Flushing in 1990[1] (a) (avg.)	Total Foliage Present on Tree: Following Shoot Flushing in 1990 (After Spray Treatment) (b) (avg.)	Percent Change in Total Foliage $\frac{(b-a)}{a} \times 100\%$
H	1	15	96%	95%	-1%
	2	15	95%	95%	0%
	3	15	79%	60%	-24%
	4	15	78%	51%	-35%
	5	15	64%	78%	22%
P	1	15	66%	92%	39%
	2	15	68%	92%	35%
	3	15	54%	86%	59%
	4	20	51%	74%	45%
	5	20	67%	84%	25%

1. Assessed trees selected for monitoring because they still retained a large complement of needles. These trees do not necessarily represent general stand condition. For example, many trees in plots 3, 4 and 5 in Block H were severely defoliated from looper feeding in 1989 and were not used for monitoring purposes.

Table 4. Defoliation of current year's foliage.

Block	Plot No.	No. Trees Sampled	Defoliation on Current Year's Foliage (a)	Defoliation Caused By Budworm Feeding[1] (b)	Defoliation on Current Year's Foliage Corrected For Budworm Feeding (a-b)
H	1	15	5%	0%	5%
	2	15	5%	0%	5%
	3	15	39%	0%	39%
	4	15	41%	0%	41%
	5	15	16%	0%	16%
P	1	15	31%	17%	14%
	2	15	21%	5%	16%
	3	15	44%	40%	4%
	4	20	70%	42%	28%
	5	20	65%	45%	20%

1. Based on estimated defoliation up to June 24th prior to any spraying against looper and prior to any significant feeding by looper.

Percent survival in spray blocks in northern New Brunswick were much lower than the untreated plots in Charlotte County (Figure 5). In Block P (2 x B.t.), 5 1/2 days after final treatment, mean survival was 17% from hatch to larval index of approximately 3.0 (July 5). In Block H (Fen. + B.t. + Fen.), 4-5 days after final treatment, mean survival was 25% from hatch to larval index of 3.1 (July 10-11). In contrast there was 49% survival from hatch to larval index of 3.6 - 4.0 (July 12-13) in the untreated plots in Charlotte County. Data were not available from the untreated plots to calculate mean survival for the same period as in the spray blocks; that is, from hatch to larval index of 3.0-3.1. Since natural mortality increases over time, it is assumed that differences in survival between sprayed and untreated plots would be even more significant for an identical larval development period. These data should be interpreted with caution as differences are not necessarily due to insecticide-induced mortality. Hemlock looper outbreaks in several other jurisdictions have been known to rise, and collapse quickly (Martineau, 1984). It is, therefore, possible that the populations in Charlotte County and in the spray blocks in northern New Brunswick were at different phases in their outbreak cycle and were each behaving in a biologically distinct manner. Hence, density-dependent factors would possibly contribute to differences in observed survival rates. The Charlotte County untreated population had spring larval counts less than 10 larvae/branch in all but one plot (which averaged 38 per branch). This compares to much higher plot averages of 6 to 50 larvae/branch in the northern sprayed population.

The observed difference in overall mean survival between the monitored blocks is mostly accounted for by the survival between plots. For example, all five plots in Block P (2 x B.t.) and three plots in Block H (Fen. + B.t. + Fen.) had low survival. The remaining two plots in Block H had high survival.

These two plots in Block H were the only ones that experienced a net decline in total foliage on trees (Table 3). These plots also had the most loss of current year's foliage (Table 4).

3.4 Change in Egg Counts Following Spray Applications

Although the primary objective of the spray program was to prevent significant foliage loss which could kill or severely weaken trees in a single year, the secondary objective was to determine if insecticide application could cause enough additional mortality to significantly reduce the number of eggs in the fall of 1990. The status of the looper outbreak in 1991 would be diminished if such a reduction occurred.

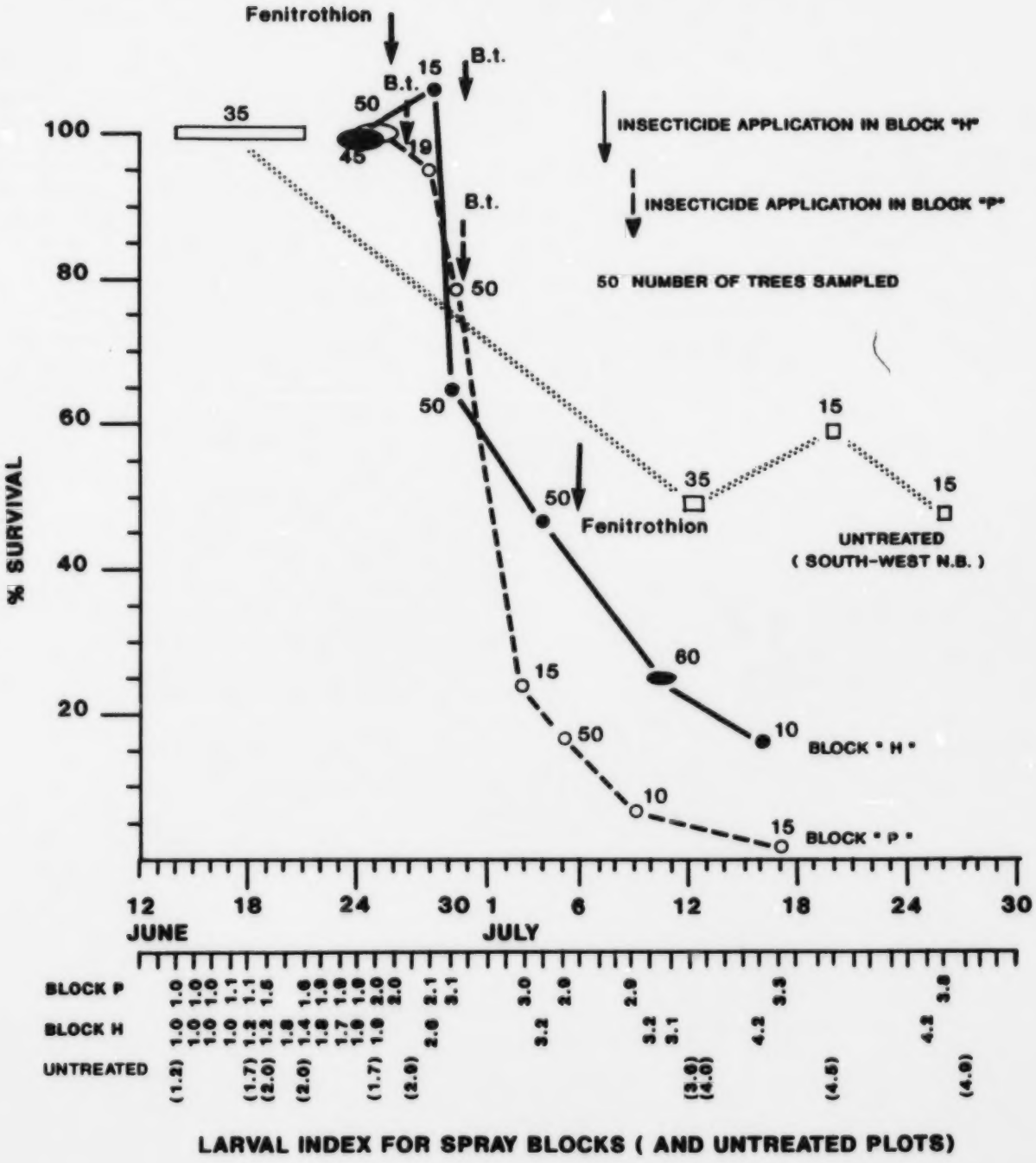


Figure 5. Survival of hemlock looper over time and by larval development index. (Untreated plots are not "controls" - see text).

Egg counts from the fall and winter of 1989/90 to the fall of 1990 (Table 5) were reduced in all plots in the insecticide treated blocks. Reductions in 3 plots in Block H (Fen. + B.t. + Fen.) ranged from 92-97% and 31-65% in the remaining two plots. Reductions were high in all five plots in Block P (2 x B.t.), ranging from 91-100%. In contrast, untreated plots in Charlotte County generally remained unchanged or increased (Table 5). These were the same 7 untreated plots which had higher larval survival than the sprayed plots. The same observation applies for changes in egg counts as was stated for differences in larval survival - the looper populations in Charlotte County and in the spray blocks in northern New Brunswick may be at different phases in their outbreak cycle, hence density-dependent factors might contribute to observed differences in egg counts. It is impossible to state without reservation that reductions in egg counts following spraying were due to insecticide-induced mortality or an abrupt natural decline in the outbreak because there was no adjacent unsprayed population in the same geographical area. However, field observations did not reveal any diseased larvae in either the treated or untreated areas. Fungal infections in larval populations have been shown to play a key role in the collapse of hemlock looper outbreaks (Otvos, 1973).

Table 5. Change in hemlock looper egg density from the fall and winter of 1989/90 to the fall of 1990.

Block	Plot No.	(1989/90) Egg Count Prior to Treatment[1] (a)	(1990) Egg Count After Treatment[1] (b)	Percent Change in Egg Count $\frac{b-a}{a} \times 100\%$	Sample Size (trees/plot)
H	1	5.3	0.2	- 96%	10
(Fen.+	2	10.5	3.7	- 65%	10
B.t. +	3	30.4	20.9	- 31%	10
Fen.)	4	89.9	7.3	- 92%	10
	5	85.5	2.6	- 97%	10
P	1	12.8	1.1	- 91%	10
(B.t. +	2	11.9	0	- 100%	10
B.t.)	3	13.3	0.5	- 96%	10
	4	29.0	0.8	- 97%	10
	5	9.5	0.4	- 96%	10
Char-	1	7.8	3.0	-62%	5
lotte	2	1.8	13.2	633%	5
County	3	8.6	10.0	16%	5
(Not	4	8.2	6.8	-17%	5
Sprayed)	5	6.4	6.2	-3%	5
	6	0.4	8.0	1900%	5
	7	0.6	5.0	733%	5

1. An additional step was added to the bleach extraction process in the fall of 1990, resulting in a slightly higher recovery of eggs from foliage (Appendix C). Tests made by DNRE (unpublished data) suggest that the egg counts from the winter of 1989/90 represent 84% of total expected had the additional step been implemented for that year.

4. AERIAL ASSESSMENT OF DEFOLIATION CAUSED BY HEMLOCK LOOPER

An aerial survey was conducted in late summer (August 15 and 23) to sketch map feeding damage caused by hemlock looper in 1990. An area of approximately 130 000 ha was flown in northern New Brunswick and approximately 80 000 ha in the southwestern part of the province. Damage was limited to northern New Brunswick in the Christmas Mountains area. The area of defoliation attributed to hemlock looper during the survey was 3 477 ha, of which 78% included spruce budworm defoliation still visible from the air (Figure 6).

When sketch maps of defoliation were overlayed on maps of spray blocks for 1990, it was found that 1 822 ha (9%) of the 21 160 ha sprayed was defoliated by looper, or looper in association with spruce budworm. On a treatment basis, 9% of the area treated with Fen. + B.t. + Fen. (Blocks H & L) and 8% of the block treated with 2 x B.t. (Block P) had detectable defoliation.

5. FORECAST FOR 1991

Interpretations of egg counts to generate a forecast in New Brunswick are based on information available primarily from research done in Newfoundland. The only data for New Brunswick comes from results of surveys done by DNRE in 1989-90. Based on egg samples from thirty-five plots sampled in the fall of 1989, it was found that counts up to 9 eggs/100-cm branch per plot had less than 10% needle loss of current year's foliage and less than 17% needle loss for all foliage classes combined (unpublished data). There is yet no looper population in New Brunswick with greater than 9 eggs/branch/plot that has not been treated with insecticide, so forecast curves do not exist for local data.

For their 1990 hemlock looper forecast, Forestry Canada officials in Newfoundland classed an egg density of 1-3 eggs/branch as "low" and 4 or more eggs/branch as "moderate to high density" (Clarke *et al.*, 1990). An analysis published recently by Forestry Canada (Newfoundland and Labrador Region) classified damage by looper as light at $\leq$ 4 eggs per branch and severe at $\geq$ 10 eggs per branch (Dobesberger, 1989). Recent discussions with Dobesberger (personal communications, October, 1989) suggest the threshold could be increased to $\geq$ 10 eggs/branch before significant defoliation occurs. For this reason, 10 eggs/branch was adopted as the population threshold at which moderate levels of feeding damage might be expected on fir in this Province. A 100-cm branch from the lower crown of each sample tree was adopted as the sampling unit believed to best reflect population density (Dobesberger, personal communications, October, 1989).

In the fall of 1990, 231 plots were sampled in northern and southwestern New Brunswick in zones known to have some looper activity. At each plot a 100-cm branch was removed from the lower crown of each of

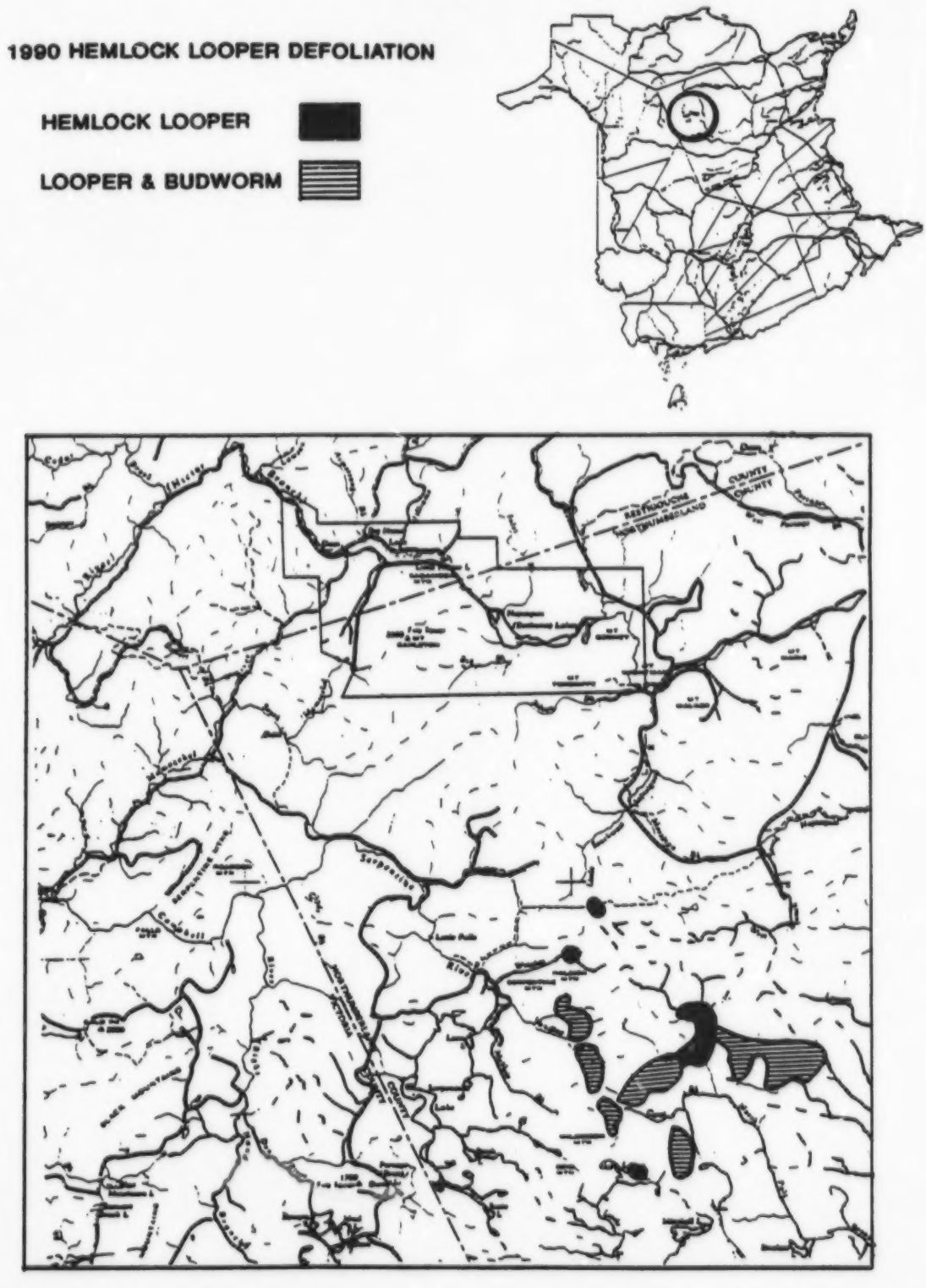


Figure 6. Area of defoliation attributed to hemlock looper in New Brunswick in 1990.

5 trees. Branches were taken back to a lab in Fredericton where the eggs were extracted. The extraction process, similar to that used in 1989, is a bleach extraction technique based on operational procedures developed by Forestry Canada - Newfoundland and Labrador Region (Details in Appendix C).

In northern New Brunswick, results of the egg survey were very encouraging as indicated by the decline in egg counts in the spray blocks (Section 3.4, Table 5). Egg counts both inside and outside the spray blocks were generally low; only one plot had 10-19 eggs/branch, and only one plot had more than 20 eggs/branch. Unfortunately, accessibility is limited throughout the area; it is believed that undetected pockets of higher looper populations do exist, as suggested by several thousand hectares of defoliation that occurred, often in areas inaccessible for conducting an egg survey. A boundary was drawn around the zone having 10 or more eggs/branch and/or looper defoliation in 1990, thus resulting in delineation of an area of 22 692 ha in which pockets of defoliation are suspected to occur in northern New Brunswick in 1991 (Figure 7).

In addition, the egg survey revealed an apparent increase in populations in Charlotte County in southwestern New Brunswick. For instance in 1989, limited sampling revealed egg counts which never exceeded 9 per branch. In 1990, seven locations had average egg counts in the range of 10-19 per branch. These locations suggest an area of about 6 771 ha in southwestern New Brunswick in which pockets of defoliation are suspected to occur in 1991 (Figure 7).

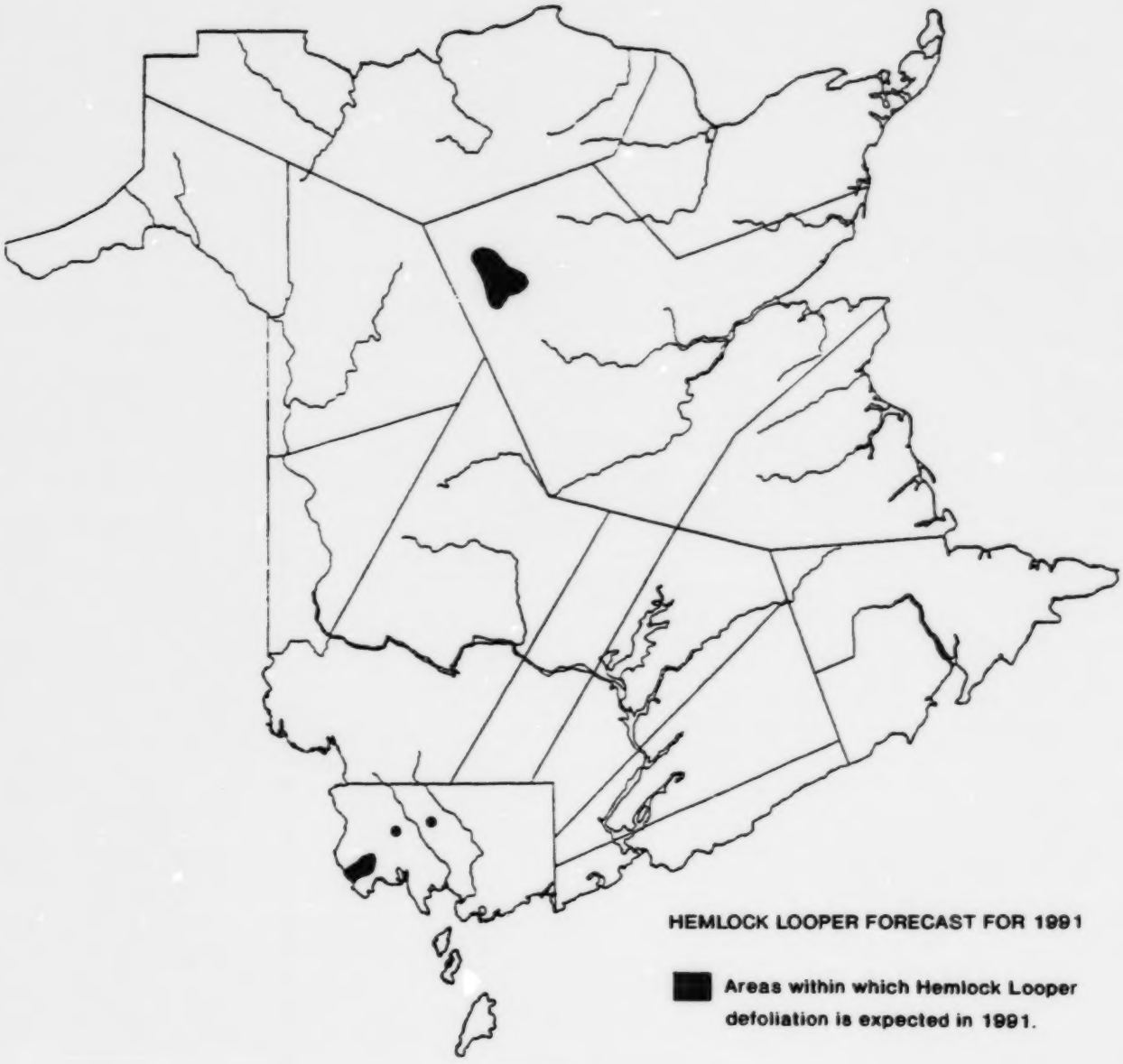


Figure 7. Hemlock looper forecast for 1991 in New Brunswick, based on egg surveys and aerial surveys of defoliation in 1990.

REFERENCES

Clarke, L.J., W.J. Sutton, E.C. Banfield, D.M. Stone, D.S. O'Brien, K.E. Pardy and G.C. Carew, 1990. Forest insect and disease conditions in Newfoundland and Labrador in 1989. Forestry Canada, Newfoundland and Labrador Region. Info. Rep. N-X-275. 41 pp.

Davies, D. 1990. Forest Protection Ltd. 1990 Program Report. 7 pp. F.P.L., Comp. 5, Site 24, R.R. #1, Fredericton, N.B.

Dobesberger, E.J. 1989. A sequential decision plan for the management of the eastern hemlock looper, Lambdina fiscellaria fiscellaria (Lepidoptera: Geometridae), in Newfoundland. Can. J. For. Res. 19:911-916.

Magasi, L. P. 1990. Forest pest conditions in the Maritimes in 1989. Information Report M-X-177. Forestry Canada - Maritimes Region. 77 pp.

Martineau, R. 1984. Insects harmful to forest trees. Multiscience Publications Ltd. 261 pp.

Otvos, I. S. 1973. Biological control agents and their role in the population fluctuations of the eastern hemlock looper in Newfoundland. Environ. Can., Can. For. Serv., Nfld. For. Res. Cent., St. John's Nfld. Inf. Rep. N-X-102. 34 pp.

APPENDIX A

Scatter diagram of relationship between hemlock looper larval hatch and larval development[1] versus accumulated degree days for period April 1 - July 31, 1990. A threshold of 3°C was used to calculate degree day accumulations.[2]

1. Calculation of Larval Development Index is explained in Appendix B.

2. In conjunction with the spruce budworm spray program, DNRE calculates degree day accumulations at many weather stations around the Province, using 3°C as the threshold. This provides a relative measure of spruce budworm larval development at locations throughout the Province. Since temperature data are available in this format on an annual basis, it was decided to use a 3°C threshold for comparing degree day accumulations with hemlock looper development.

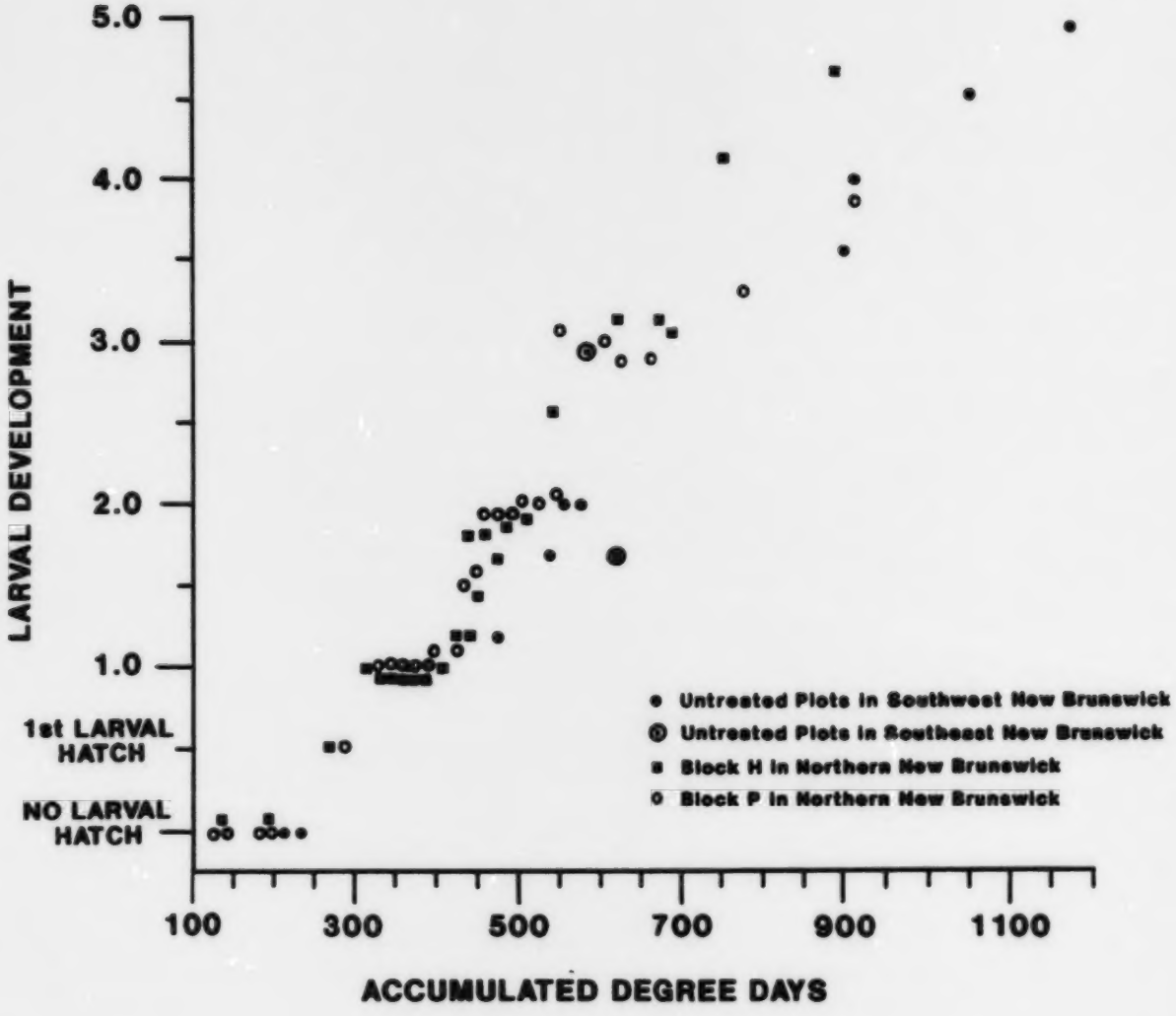


Figure A-1. Scatter diagram of hemlock looper larval development versus accumulated degree days from April 1 to July 31, 1990 (threshold of 3°C).

APPENDIX B

Summary of hemlock looper larval development at time of block openings and at time blocks were sprayed.

Table B-1. Summary of hemlock looper larval development[1] at time of block openings and at time of spraying.

BLOCK		1st APPLICATION		2nd APPLICATION		3rd APPLICATION	
		OPENED	SPRAYED	OPENED	SPRAYED	OPENED	SPRAYED
"H"	Opening Dates and Spray Dates	June 20	June 25 & 26	June 28 - Block with 2nd priority application	June 29 & 30 after 2nd	Minimum 5 days	July 6
	Larval Development Index[2] (LI)	LI = 1.0-2.0, depending on plot	LI = 1.1-2.0, depending on plot	LI = 2.4-2.8, depending on plot	LI = slightly greater than 2.4-2.8, depending on plot	LI = 3.3	L1 = slightly greater than 3.3
"L"	Opening Dates and Spray Dates	June 20	June 27 & 28	June 28 - Block with 3rd priority	June 30 and July 1	Minimum 2 days after 2nd application	July 3
	Larval Development Index (LI)	LI = estimated range of 1.0-2.0	LI = estimated at 1.1-2.0	LI = estimated at 2.1-2.8	LI = estimated at 2.4-3.1	LI = estimated at 3.3	LI = estimated as slightly greater than 3.3
"P"	Opening Dates and Spray Dates	June 20	June 27	June 28 - Block with 1st priority	June 29	N/A	N/A
	Larval Development Index (LI)	LI = 1.5-1.7, depending on plot	LI = slightly greater than 1.9-2.0, depending on plot.	LI = 2.1-2.6, depending on plot	LI = 3.1	--	--

1. The mean larval index over time for Blocks H and P is shown in Figure 5 of the text.

2. Larval Development Index (LI) is calculated by the following formula: LI = {[(Number of 1st Instar Larvae) x 1] + [(Number of 2nd Instar Larvae) x 2] + [(Number of 3rd Instar Larvae) x 3] + [(Number of 4th Instar Larvae) x 4] + [(Number of 5th Instar Larvae) x 5]} + Total Number Larvae

APPENDIX C

Hemlock looper egg extraction process as used in New Brunswick.

HEMLOCK LOOPER EGG EXTRACTION PROCESS AS USED IN NEW BRUNSWICK

- At the start of each day, 200 ml of Javex bleach (6% sodium hypochlorite) and 9.8 litres of cold tap water are put in each 14-litre pail to be used for the wash. Thus, a 2% solution of Javex is used.

- Each branch, 100-cm long, is cut into small pieces (approximately 8 cm) and placed in the Javex and water solution.

- The branches are lightly stirred every 15 minutes. After 45 minutes in the solution, the rinsing process begins.

- The solution of Javex and water is retained and recycled each day.

- To recycle the solution it is poured from the 14-litre pail, through a 3-sieve system into a 23-litre pail. The top sieve, 850 micron (#20) catches the branch; the middle sieve, 425 micron (#40) catches some of the larger particles of dirt and the hemlock looper eggs; and the bottom sieve, 212 micron (#70), catches finer particles of dirt that go through the other two sieves. Material on this sieve is discarded. This makes the recycled solution much cleaner. Note, this is the only use of the number 70 sieve as all the eggs are caught in the number 40 sieve.

- The two other sieves are placed in the wash sink, with the number 20 sieve on top of the number 40 sieve. The branch is lightly sprayed with water and the hemlock looper eggs as well as particles of dirt and lichen are rinsed through the number 20 sieve into the number 40 sieve.

- The branch is then re-immersed in a bucket of water (= double rinse) and then poured over the number 20 and 40 sieves; the branch is lightly sprayed with water as described in the previous step.[1]

- Everything on the number 40 sieve is then rinsed down and funnelled into a mason jar.

- The contents, or a portion of the contents of the mason jar are poured into a Buckner funnel lined with grided filter paper. Numerous filter papers are used per jar, to avoid the eggs being buried under dirt particles. Therefore the amount of dirt per sample dictates the number of filter papers used per sample.

- Using a dissecting microscope (6.4x magnification) the hemlock looper eggs are identified and the number of eggs/branch sample is recorded.

---

1. The double rinse procedure was implemented in the fall of 1990, after testing revealed that an average 16% of the total eggs were not dislodged in the first rinse. (The double rinse had not been used in processing foliage samples collected during the fall and winter egg survey of 1989/90).